SPREAD SPECTRUM COMMUNICATION SYSTEM AND TRANSMISSION POWER CONTROL METHOD THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a spread spectrum communication system, and in particular to a spread spectrum cellular system in which a plurality of terminals simultaneously communicate with a base station, and mobile terminals and a transmission power control method applied to the spread spectrum cellular system.

2. Description of the Related Art

FIG. **9** shows an example of a conventional spread spectrum cellular system. A plurality of base stations **100** (**100**-a, **100**-b) connected to a switching unit **10** are distributed to form a plurality of cells **1** (**1***a*, **1***b*). In each cell, a plurality of mobile terminals **300** (**300-1**, **300-2**; **300**-j, **300**-k) communicate with a base station **100**. There has been known a method of using orthogonal codes Wi unique to respective terminals as spreading codes of signals transmitted from each base station **100** to each of terminals included in a cell in such a spread spectrum cellular system.

As represented by codes **W0**, **W1**, **W2** and **W3** shown in FIG. **10**, for example, orthogonal codes have such a property that the inner product performed on two arbitrary codes included in the codes **W0**, **W1**, **W2** and **W3** over an orthogonal code span becomes "0."

Therefore, the base station assigns orthogonal codes Wi (i=1, 2, . . . , n) respectively unique in a cell to a plurality of terminals **300-1** through **300**-n located in the cell, and spreads a signal or data addressed to one terminal **300**-i by using an orthogonal code Wi unique to that terminal **300**-i. The above described terminal **300**-i de-spreads a signal received from an antenna by using the orthogonal code Wi assigned to itself. By doing so, transmitted signals addressed to other terminals located in the cell which are orthogonal to the transmitted signal addressed to the terminal **300**-i are completely removed in the process of the above described de-spreading process and hence they do not act as interference.

A communication method thus employing spreading with orthogonal codes for communication from each base station to mobile terminals is described in U.S. Pat. No. 5,103,459, for example.

In a spread spectrum cellular system using orthogonal codes, however, signals transmitted from other base stations forming adjacent cells arrive at each terminal besides the signal transmitted from the base station. In this case, signals transmitted from other base stations are not orthogonal to the signal transmitted from the base station in the cell, and hence they cannot be removed in the above described cell by de-spreading process using the unique orthogonal code Wi. That is to say, in receiving operation of each terminal, signals transmitted from base stations of adjacent cells act as an interference cause (noise).

FIG. **11** is a diagram showing the influence of the above described signals transmitted from other base stations and received by each terminal.

Received power of the signal transmitted from the base station is attenuated as the distance from the base station is increased. In a terminal, such as **300***j*, located near the base station and located near the center of the cell, therefore, received power **910** of the signal from the base station in the cell is large whereas received power **911** of the signal coming from other base stations located outside the cell and functioning as interference becomes small. As a result, a high signal-to-noise ratio is obtained. In a terminal, such as **300***k*, located near the boundary of the cell, received power **912** of the signal from the base station located in the cell is weak whereas interference from adjacent cells is received with power **913** larger than that of the above described terminal **300***j*. As a result, the signal-to-noise ratio is degraded.

For the above described reason, it is desired to control transmission power in the cellular system according to the positional relation with respect to a terminal so that a signal to be transmitted from each base station to a terminal may be outputted with small transmission power for the terminal **300***j* located near the center of the cell and with large transmission power for the terminal **300***k* located on the periphery of the cell.

Such a transmission power control method as to change the transmission power according to the terminal position is described in "On the System Design Aspects of Code Division Multiple Access (CDMA) Applied to Digital Cellular and Personal communications Network," by A. Salmasi and K. S. Gilhousen, IEEE VTS 1991, pp. 57–62, for example.

According to the control method described in the aforementioned paper, each terminal measures the signal-to-noise ratio of a received signal by using a circuit configuration shown in FIG. **12**, for example, and transmits a power control signal demanding adjustment of transmission power to the base station. By using circuit configurations shown in FIGS. **13** and **14**, the base station conducts transmission signal power control operation in response to the above described power control signal.

FIG. **12** shows the configuration of a transmitter and receiver circuit of a conventional terminal.

A signal received by an antenna **301** is inputted to a radio frequency circuit **303** via a circulator **302** and converted therein to a base band spread spectrum signal.

The above described base band spread spectrum signal is inputted to a first multiplier **304**, therein multiplied by pseudo-noise PN generated by a pseudo-noise generator **305**, and subjected to a first stage of de-spreading process. The above described pseudo-noise PN has a noise pattern set so that the pseudo-noise PN may become the same as a unique pseudo-noise PN generated by a PN generator **103** of the above described base station when the position of the terminal is registered in the base station.

The signal subjected to the first stage of de-spreading process is inputted to a second multiplier **307**, therein multiplied by an orthogonal code Wi generated by an orthogonal code generator **306** and assigned to the terminal, and subjected to a second stage of de-spreading process.

The signal subjected to the second-stage of de-spreading process is inputted to an accumulator **308**. The signal received during a predetermined time is accumulated by the accumulator **308**. The accumulated signal is decoded by a decoder **309** to form received data.

Conventionally in each terminal, the signal-to-noise ratio of the received signal is measured by utilizing the fact that the variance of probability density distribution relating to the amplitude of the received signal indicates the noise power and its average indicates the amplitude of signal. For the purpose of this measurement of the signal-to-noise ratio, the output of the accumulator **308** is inputted to an absolute